

Cogeneration Case Studies of the DoD Fuel Cell Demonstration Program

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Abstract

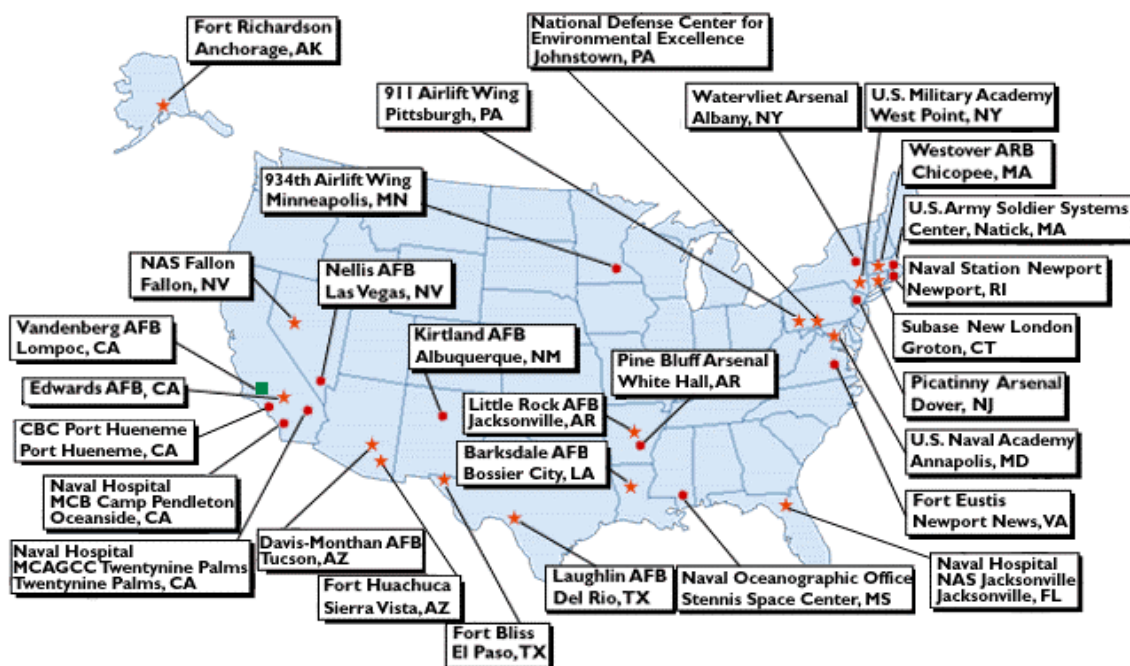
Under the Department of Defense (DoD) Fuel Cell Demonstration Program managed by USACERL, 200 kW Phosphoric Acid Fuel Cell (PAFC) power plants were installed and made operational at 30 DoD sites located throughout the U.S. The thermal output from these power plants is being used in a variety of cogeneration applications including pre-heating boiler make-up water, supplying heat for domestic hot water (DHW), space heating, HVAC system reheat, pre-heating condensate return, and supplying heat for swimming pools. All of the fuel cells in the DoD fleet are being monitored for electrical and thermal efficiency, and total availability. As of January 1, 2000, 30 PAFC power plants have generated 91,720 MWh of electricity, 76,192 MMBtus of thermal energy, and saved \$3.6 million in displaced electrical and thermal energy costs.

Introduction

Cogeneration is the simultaneous production of two forms of useful energy. Each of the 30 fuel cells in the DoD Fuel Cell Demonstration Program generated electrical and thermal energy which was then utilized at the individual sites. Due to the scope and breadth of the DoD program, a wealth of experience and lessons learned were generated that can benefit future users of fuel cell power plants. This paper summarizes the cogeneration applications, major thermal interface issues and also presents three case study examples from the DoD program.

DoD Demonstration Program

A complete list of sites can be found at the DoD Fuel Cell Demonstration website at <http://www.dodfuelcell.com>. There are 9 Army sites, 11 Air Force sites, 9 Navy/Marine sites and one DoD industrial research facility.

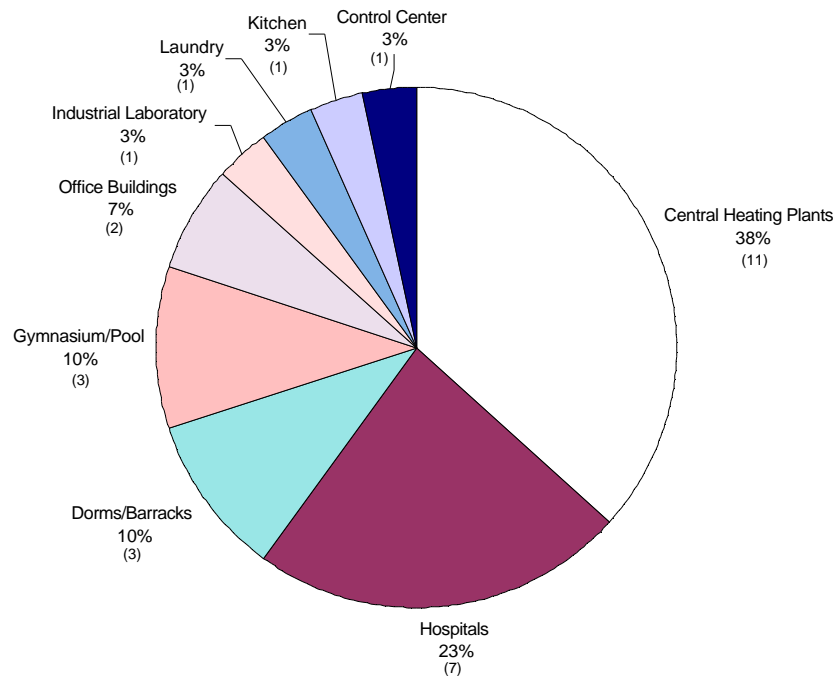


The DoD fuel cell fleet consists of 15 ONSI PC25 Model C units, 14 Model B units and one Model A unit. The Model C power plants (PC25C) are ONSI's latest evolution of its power plant and include reductions in size, weight and costs as well as other enhancements to performance and option availability. The goals of the demonstration program are to stimulate growth and economies of scale in the fuel cell industry and to determine the role of fuel cells in the DoD's long-term energy strategy. The DoD program tested fuel cells under a wide variety of climates, from very cold and wet, to very hot and dry.

All of the fuel cells are thermally interfaced to their respective facility, with seven of the fuel cells configured to provide back-up power should a utility grid outage occur. The fuel cell electrical interfaces at the DoD bases are relatively straightforward. The fuel cell was connected to a building through an existing electrical panel or a transformer of at least 300 kVA in size. Because military bases have their own grid, the fuel cell can be tied into either a building load or directly into the base grid. A dedicated load of not more than 200 kW can be tied in at the fuel cell's grid-independent terminals so that this load could be served during utility grid outages.

Cogeneration Applications

There is a broad range of building applications within the DoD Fuel Cell Demonstration Program. These include central heating plants, hospitals, dormitories/barracks, gymnasium/pools, office buildings, industrial laboratory, laundry, kitchen and a control center. Thermal loads include boiler make-up water, boiler steam loop condensate return, hydronic space heating, HVAC reheat systems, industrial evaporative process, domestic hot water (DHW) - for showers, kitchen loads, and laundry, commercial laundry hot water, and absorption cooling. The ONSI PC25 fuel cells deliver approximately 700,000 Btu/hour of hot water at 140°F. Six of the fuel cell power plants have the high-grade heat exchanger option which can deliver up to half of the total output (~350,000 Btu/hour) as 250°F pressurized hot water. The remainder of the thermal output, including under-utilized high-grade heat, is available at 140°F through the standard low-grade heat exchanger.



Fuel Cell Thermal Interface Issues

The wide variety of cogeneration applications within the DoD Fuel Cell Demonstration Program brought to light several relevant issues during the site selection, design and installation phases of the program. A number of these issues specific to the thermal interfaces are briefly highlighted below and should be considered when evaluating a fuel cell cogeneration application.

Potable water requirements - All of the DoD PAFC power plants have double-walled heat exchangers (an ONSI option) so that potable water could be run through the fuel cell. If potable water is not needed for the application, then the standard heat exchanger will satisfy the requirements and minimize costs.

Retrofit system design - Each of the fuel cells in the DoD program was integrated into an existing building application. In order to ensure that the site thermal requirements were always met, the fuel cell thermal interfaces were designed to augment, rather than replace, the existing thermal system. In the event where the fuel cell was not operational, the existing system could function as it did prior to the fuel cell installation. The three case studies discussed in this paper provide more specific details to this approach.

High-grade/low-grade heat exchanger interfaces - In order to get the full 700,000 Btus of available thermal output from the fuel cell with a high-grade heat exchanger, the low-grade heat exchanger must also be interfaced to a building application. Interfacing to both heat exchangers increases the design, material and installation costs, and the economics of this type of design should be evaluated.

Temperature compatibility - Site temperature requirements are critical to both site selection and system design considerations. Site temperatures that exceed the standard power plant capability of ~140°F hot water are not good candidate sites unless the high-grade heat exchanger option is employed. Typically, the lower the incoming water temperature, the higher the potential heat transfer from the fuel cell. Boiler make-up water, from a municipal water system, is an example of a good low temperature source. Supply temperatures to the fuel cell should be 20°F or more below the fuel cell's output capability.

Pipe material compatibility - One of the DoD sites has a stainless steel piping loop to handle the boiler plant's deionized make-up water system. Stainless steel piping had to be specified for the fuel cell interface in order to be fully compatible with the site.

Low/intermittent thermal requirement - Many sites did not have significant thermal requirements or had peak periods followed by periods of little or no demand. One solution was to interface multiple loads to the fuel cell in order to increase potential thermal utilization. For example, a DHW loop and a space heating loop were interfaced at one site. To handle more of a peak period load requirement, storage tanks were added to store fuel cell heat during low thermal demand periods at the sites.

Water separation issues - chemicals such as chlorine in pools are not compatible with the fuel cell heat exchanger. In the DoD Program, external titanium heat exchangers were used to separate the pool load from the fuel cell's thermal hot water loop.

Changes in site characteristics - On a few occasions, site characteristics changed after the fuel cell was installed and this ultimately impacted the thermal utilization. On one boiler plant, leaks in the steam distribution loop were repaired and the amount of make-up water required was dramatically reduced.

Case Studies

The following pages present summaries of three cogeneration case studies from the DoD Fuel Cell Demonstration Program. The three thermal applications include a central heating (boiler) plant, a space heating loop and a swimming pool. Each case presents different design and performance characteristics. The primary focus of the discussion is on the thermal interfaces since, as previously mentioned, the electrical interfaces were generally straightforward.

It should be noted that the 700,000 Btu/hour of thermal output from the ONSI PAFC power plants was often greater than what a typical military cogeneration application could utilize. In the site evaluations, typical thermal utilization projections ranged from 25% to 75%, with some sites being able to utilize all of the thermal output. If a site could utilize 50% of the available thermal, this was considered a good potential application during the DoD site selection process.

Case Study 1 - Central Heating Plant



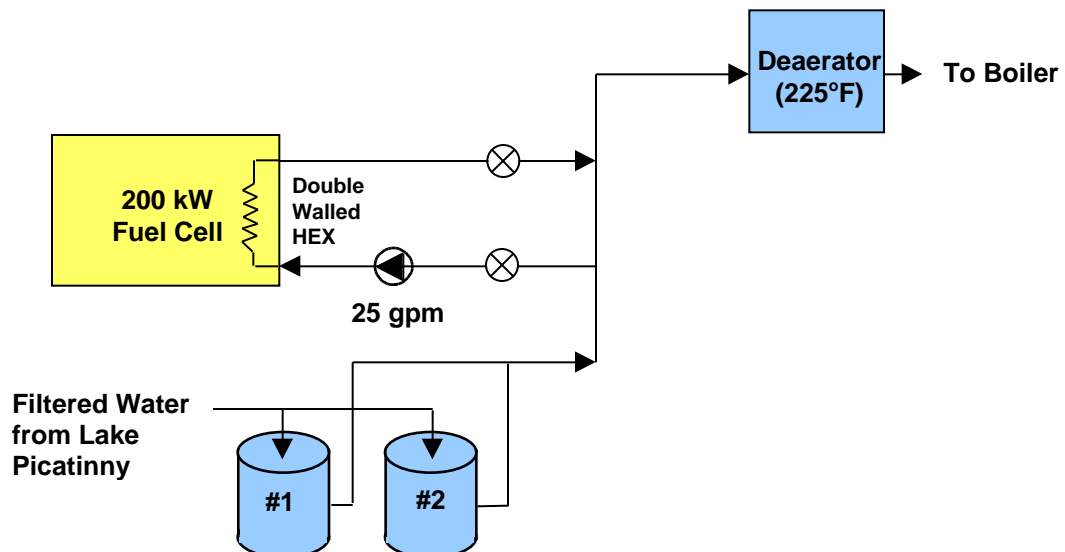
DoD Facility:	Picatinny Arsenal Dover, NJ
Installed:	October 1995
Fuel Cell Model:	PC25B
Thermal Interface:	Pre-heat boiler make-up water taken from nearby Lake Picatinny.
Electrical Interface:	Grid-connected through an existing panel.

Description: The central heating plant provides steam throughout the base for space heating, hot water and humidity control. There is no condensate return in the steam distribution system, so the boilers operate on 100% make-up water. Rather than relying on a municipal water system, the make-up water is taken from nearby Lake Picatinny. The lake water is filtered prior to entering the boiler plant. After passing through water softeners, 25 gpm of make-up water is passed through the fuel cell heat exchanger to "pre-heat" it prior to entering the deaerator.

Results: The Picatinny Arsenal fuel cell has the highest thermal recovery rate of any of the fuel cell installations. The average rate of recovery is >750,000 Btu/hour. When make-up water temperatures are low in the winter, heat recovery rates exceeding 1 MMBtu/hour have been achieved. There have been several months in which the average heat recovery rate exceeded 1 MMBtu/hour.

Savings: The initial projected energy bill savings for this site is as follows:

Electrical Savings:	\$121,000
Thermal Savings:	\$ 25,000
Natural Gas Costs:	(\$52,000)
NET SAVINGS:	\$ 94,000



Case Study 2 - Hospital Space Heating Loop



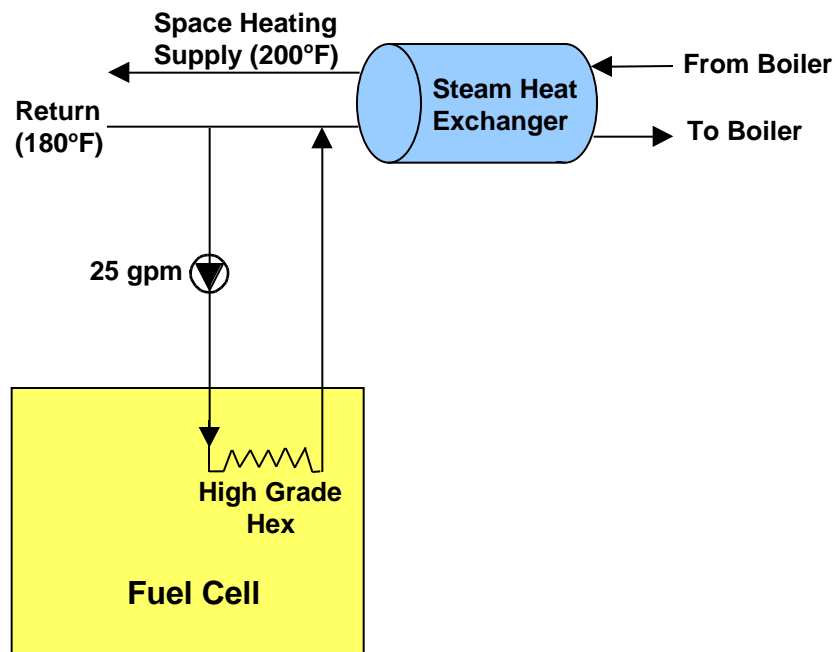
DoD Facility:	Edwards Air Force Base Edwards AFB, CA
Installed:	July 1997
Fuel Cell Model:	PC25C
Thermal Interface:	Pre-heat space heating return loop prior to entering site steam heat exchanger
Electrical Interface:	Grid-connected to site transformer.

Description: The fuel cell is located at the base hospital and is thermally connected to a steam heat exchanger serving the building's space heating loop. Space heating is required year round due to the cold nights and HVAC reheat requirements. Fluid from the space heating return loop is passed through the fuel cell's high-grade heat exchanger before re-entering the steam heat exchanger. This configuration allows the steam system to operate when either the fuel cell is unavailable or unable to generate high enough temperatures to meet the needs of the space heating loop.

Results: It was estimated that the site would utilize about half of the high-grade heat exchanger's total output capacity. No data is available to document the amount of fuel cell thermal energy utilized by the space heating system, but all systems have been as designed.

Savings: The initial projected energy bill savings for this site is as follows:

Electrical Savings:	\$122,000
Thermal Savings:	\$ 3,000
Natural Gas Costs:	(\$29,000)
NET SAVINGS:	\$ 96,000



Case Study 3 - Swimming Pool



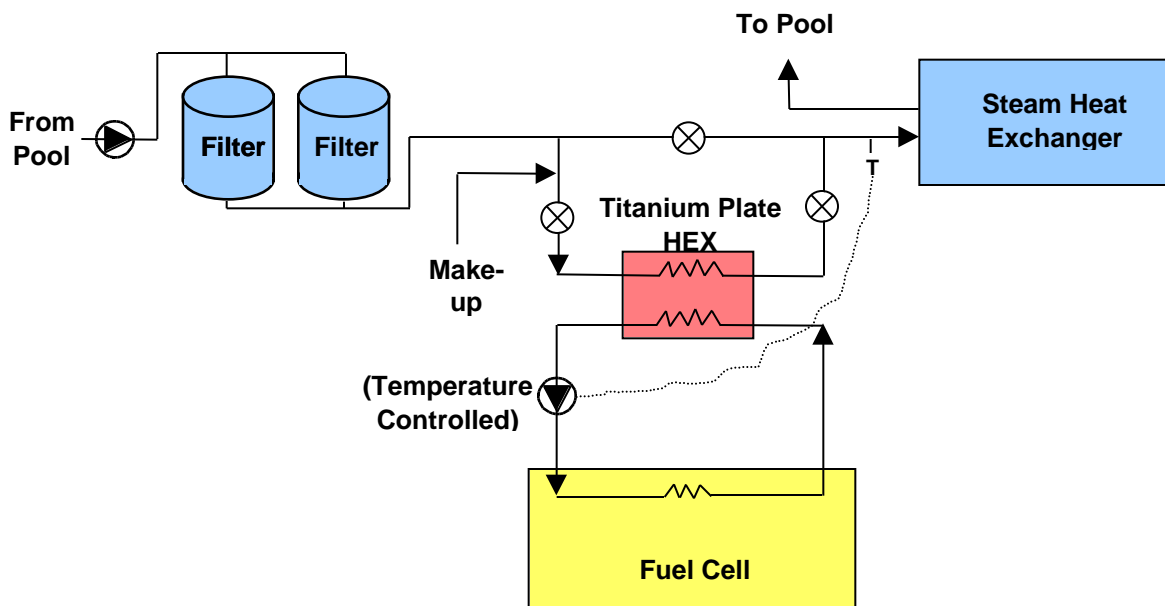
DoD Facility:	Fort Eustis Newport News, VA
Installed:	September 1995
Fuel Cell Model:	PC25B
Thermal Interface:	Make-up water and pool recirculation loop.
Electrical Interface:	Grid-connect to transformer Backs up dedicated electrical load during grid outage.

Description: The fuel cell thermal output is circulated through an intermediate titanium heat exchanger that provides heat to the pool recirculation loop. A titanium heat exchanger was required to separate the corrosive pool chemicals from the internal fuel cell heat exchanger. Pool make-up water is directed through the intermediate heat exchanger to add heat prior to entering the pool.

Results: During the installation of the fuel cell, a severe pool water leak was discovered and subsequently repaired. This dramatically reduced the amount of make-up water previously indicated in records reviewed during the site screening. The fuel cell provides approximately 125 kBtu/Hour of thermal energy to the pool (~18% of available thermal output). Due to economic factors related to the natural gas utility's rate structure, Fort Eustis elects to shut the fuel cell down between November and April each year.

Savings: The initial projected energy bill savings for this site is as follows:

Electrical Savings:	\$ 62,000
Thermal Savings:	\$ 20,000
Natural Gas Costs:	(\$41,000)
NET SAVINGS:	\$ 41,000



Summary/Conclusions

The DoD Fuel Cell Demonstration Program has shown that fuel cells can successfully be integrated with a variety of building applications in a variety of climates. The greatest cogeneration challenges are typically the thermal interface design/integration issues. Consideration should be given to site temperature and load demand characteristics, compatibility of materials, water separation requirements, seamless integration with existing building systems, and potential future changes to site requirements. Please visit the DoD Fuel Cell Demonstration website at <http://www.dodfuelcell.com>.